Ontario's Drive Clean Program: A Preliminary Review of Year One Data (1999)

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Abstract

The report is an analysis of emissions data collected under Phase I of Ontario's Drive Clean program, a mandatory vehicle inspection and maintenance (I/M) program, from start up on January 2, 1999 to September 30, 1999. This nine month data collection period is equivalent to half of the fleet inventory in the Phase I program area (Greater Toronto Area and Hamilton-Wentworth). Nearly 84 per cent of light-duty vehicles inspected received a pass certificate upon first inspection, with the pass rate rising to more than 95 per cent for vehicles less than five years old. The repairs undertaken on vehicles that failed their first inspection resulted in significant emissions reductions of HC, CO and Nox, well beyond the cut points for these parameters. In Year One, Drive Clean achieved reductions of 8.8% HC, 8.8% CO, and 3.5 % NOx emissions from vehicle sources in the program area. Annualized over a complete program year, the estimated emission reductions are 11.8 % HC, 11.7% CO and 4.7 % Nox. Removing the $200 repair cost limit after Year Two will result in additional reductions of 4.4 % HC, 2.9% CO, 1.1% NOx in the program area. In addition, concurrent improvements in fuel efficiency reduced the release of carbon dioxide, a greenhouse gas, by an estimated 18,500 tonnes.

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1.0 Purpose

This report presents an analysis of vehicle emissions data collected under Ontario's Drive Clean program for the period of January 2, 1999 to September 30, 1999. The analysis was used to:

- Assess the effectiveness of any repairs undertaken to better comply with the province's vehicular air emission standards;

- Quantify emissions reductions of hydrocarbons (HC), carbon monoxide (CO) and nitrogen oxides (NOx) from vehicles in the Phase I program area and the reduction in emissions that could be attributed to the Drive Clean program;

- Estimate the effect of the emission reductions on fuel savings and greenhouse gas reduction; and

- Quantify the additional reductions that will be realized when the current repair cost limit disappears.

2.0 Background

Emissions from on-road vehicles contribute to both local and long-range environmental problems: primarily smog, and to a lesser extent acid rain and climate change. Vehicular emissions, such as carbon monoxide, volatile organics and fine particulates, also exacerbate a number of human health problems and contribute to elevated morbidity and mortality rates in affected populations. Ontario's mandatory vehicle inspection and maintenance program, known as *Drive Clean*, is one method of reducing vehicular emissions.

Federal regulations set forth emission performance standards for vehicles at the time of their manufacture. However, a vehicle's emissions may increase over time due

to engine wear, improper or irregular maintenance, and tampering with or failure of emission control devices. Operating standards, including those limiting the release of air contaminants, fall under provincial jurisdiction. Drive Clean is designed to identify those vehicles that no longer operate in compliance with acceptable emission standards and ensure that the proper corrective action is taken.

Regulation 628 under Ontario's *Highway Traffic Act* requires that specified light-duty vehicles (less than 4,500 kg.: mainly passenger cars, sports utility vehicles, vans and light trucks) undergo an emissions test every two years. Such inspections, conducted at government-accredited Drive Clean facilities, are a condition of vehicle registration for all light-duty vehicles more than three years old and less than 20 years old. In addition, an emissions inspection is required upon the transfer of ownership, for vehicles 0-19 years old, whenever a safety certificate is required.

The Drive Clean requirements are set forth in Ontario Regulation 361 under the *Environmental Protection Act*. Emission standards, emission test methods and additional technical information are described in greater detail in the Ontario Ministry of the Environment's *Drive Clean Guide* and the manual *Standard Operating Procedures for Ontario's Drive Clean Facilities as Applied to Light-duty Vehicles and Non-Diesel Heavy Duty Vehicles* (version 1.30, November 15, 1999).

Federal test procedure (FTP) standards for new vehicles were progressively tightened to reflect the improvements in emission control systems introduced over the last 20 years. A ten or 15-year-old vehicle, even one maintained in excellent running condition, cannot match the pollution control efficiencies of today's models. Ontario's vehicle emissions standards, based on the FTP standards, have been amended to accommodate the relative capabilities of contemporary control systems and the effects of normal engine wear.

The Drive Clean program for light-duty vehicles requires a visual inspection of the emissions control system, checks of on-board diagnostic information, compliance with emission recalls, and either a dynamometer test or a two-speed idle test to determine emission levels of hydrocarbons (HC), carbon monoxide (CO) and nitrogen oxides (NOx). In addition, the emissions from diesel-powered vehicles are subject to a

visual opacity test. Vehicles that do not meet the emission levels or "cut points" established for a particular model, make and year, must be repaired and re-tested until they pass or receive a conditional pass.

On April 1, 1999, having a Drive Clean pass certificate became mandatory for registration renewal and ownership transfer of light-duty vehicles in the Phase I program area: the Greater Toronto Area and the Hamilton-Wentworth Region. The total light-duty vehicle fleet in this program area is estimated at approximately 2.5 million. Because the test requirement is biennial, only about half the total fleet, plus about another 20 % to account for re-sale vehicles, are tested in a 12-month period. For administrative simplicity, odd model-year vehicles are tested in an even calendar year; even model-year vehicles are tested in an odd calendar year.

In 1999, vehicles which are 1980, 1982, on up to 1996 model years, were required to pass a Drive Clean test, if the registration renewal date was on or after April 1, 1999. In other words, the actual testing period was nine months in 1999, which, in turn, limited the actual size of the fleet tested in Year One of Drive Clean to at most 75 % of the total fleet in the Phase I program area. In 2000 (Year Two of the program), 100 % of the total fleet will be tested.

The program design is based on the prediction that 80 % of the fleet will pass the initial Drive Clean test; the remaining 20 % will require a re-test.

In the first two years of the program only, vehicles which failed the initial test and require emission-related repairs prior to a re-test, were eligible for a $200 repair cost limit (RCL). This feature, common to many vehicle I/M programs in North America, was designed to soften the financial impact of repairs on low income vehicle owners. One implication of the RCL was that owners of such vehicles had an extended two years, until the next test date, to repair the above-limit emission levels.

Phase II of Drive Clean for light-duty vehicles will commence January 1, 2001 in 13 urban areas in southern Ontario. Mandatory Drive Clean testing for heavy duty vehicles went into effect on September 30, 1999.

Vehicle inspections and repairs are conducted at government-accredited automotive repair centres by trained and certified inspectors and technicians.

When fully implemented, the Drive Clean program area will include 5.2 million light-duty vehicles and 200,000 heavy-duty trucks.

3.0 Methodology

British Columbia's AirCare has been operating a vehicle inspection and maintenance program in the Vancouver area since 1991. AirCare Administrative Office was retained by the Ministry of Environment's Drive Clean Office to evaluate the emissions and vehicle data collected from the date of its program start up on January 2, 1999 through to September 30, 1999: a total of nine months. But, as noted above, because vehicle I/M became mandatory on April 1, 1999, the nine-month data collection period is actually equivalent to *half of the total eligible fleet* being subjected to emissions testing in a full program year.

The emissions and vehicle data collected at Drive Clean facilities is automatically uploaded to a central computer database, known as the Drive Clean Vehicle Emission Transaction System (VETS). The VETS information may be analyzed for purposes of quality assurance and quality control, to detect any evidence of fraud, and in order to assess the effectiveness of the program. The data is also accessed by the Ontario Ministry of Transportation and used by vehicle licensing offices to process vehicle registrations.

Inspection data was provided to the contractor on compact disk as a Microsoft Access 97 database file, exported as a flat text file, and formatted in a way suitable for input to SAS. All basic statistical analyses were performed using SAS v 6.2, and some further manipulations were added using Microsoft Excel 2000.

4.0 Findings & Discussion

4.1 Pass and fail rates

From January 2, 1999 to September 30, 1999, some 789,894 Drive Clean inspections were performed on 631,038 individual vehicles. A total of 528,472 vehicles, or 83.7 %, passed the inspection at their first attempt, while 105,714 vehicles (16.3 %) failed their first emissions testing. Table 1 indicates the pass/fail rate by vehicle model year.

Failure rates on first inspection were less than five per cent for vehicles built within the last five years. For models built between 1986 and 1993, failure rates for both cars and trucks jumped significantly to approximately ten per cent of cars and 14% of light-duty trucks. For vehicles built prior to 1986, the failures rates remained just over 50 %. Similarly, the pass rate for re-inspections is much higher for newer vehicles.

4.2 Reasons for failure

An emissions inspection measures three separate parameters (HC, NOx and CO) and most failures result from exceedances of more than one of the parameter cut points for the particular model being inspected. Overall, 74.7 % of all initial failures resulted from failure to meet an HC cut point; 49.3 % failure to meet a CO cut point; and 58.3 % failure to meet an NOx cut point. Table 2 indicates modal failure rates for each of the three parameters, by vehicle type (either passenger vehicle or truck) and by model year (from 1980 to 2000).

Table 3 shows the median emission ratio values (emission ration=emission reading/cut point) for HC, CO and NOx emission readings to cut points. Median emission ratios for initial inspections are 0.20 for CO and 0.39 for HC. For those vehicles that failed their initial inspections, the range is from 0.94 to 1.30, which indicates values of about 30 % above the cut point.

After repairs were undertaken and the failing vehicles passed a re-inspection, the median emission ratios were reduced to between 0.18 for CO and 0.51 for HC, acceptable but still somewhat higher than those vehicles which passed at the first attempt.

Vehicles which did not pass a re-inspection and received a conditional pass (upon reaching the $200 repair cost limit) had median emission ratios of between 0.99 and 1.41. It is possible that these vehicles were initially among the highest emitters in the fleet; and, their after-repair readings may still represent a substantial reduction from their initial failed readings.

4.3 Repair effectiveness

Two different measures were used to assess the *change* in emissions as a result of emission-related repairs. Measure I indictes the emission reduction achieved by the repairs. It compares the reading obtained after repairs against the failing reading that was obtained initially [(initial reading - final reading) / initial reading]. Measure II determines how complete the repairs were. It compares the final emissions to a cut point [(cut point - final reading) / cut point] for each parameter.

Note that these measures were also applied to vehicles which received a conditional pass following a re-inspection where the value of the repairs exceeded the $200 cost limit. In these cases, not all of the necessary repairs were likely completed by the vehicle owner.

The two measures were applied to the three emission parameters for each vehicle which initially failed inspection, repaired and then went through a subsequent inspection. Both measures are expressed as an index in the range of -1.0 to +1.0. A value of +1.0 for Measure I would theoretically indicate total elimination of the emission; a value of 0.0 would indicate no change. A value of 0.0 for Measure II, on the other hand, indicates the post-repair emission achieved the cut point. A positive value shows that the emission reduction *exceeded the cut point*. A negative rating for either measure means that the repair (if there was one) actually made the emission

worse than what it was before. A negative rating for Measure II also means that only a conditional pass could be achieved.

Using Measure I, the repairs for vehicles which passed a re-inspection had median values of 0.51 for HC, 0.75 for CO, and 0.53 for NOx. In other words, HC and NOx emissions have been reduced to about one-half their initial levels, and CO emissions have been reduced to about one-quarter of their initial level. Vehicles which received a conditional pass exhibited a marginal positive value for Measure I. This is expected, given that not all of the repairs were likely completed.

Using Measure II, the repairs for vehicles which passed a re-inspection obtained a median value of 0.82 for CO, 0.45 for HC and 0.60 for NOx. Comparing the median values of the two measures, we find that the repairs not only resulted in *actual* reductions for each of the emission parameters, these reductions were below the cut points by substantial amounts.

In contrast, conditional pass vehicles ($200 repair limit) showed a negative Measure II median values for both HC and NO, indicating emissions continued to exceed the cut point, and a very slightly positive value for CO. Most vehicles that obtained a conditional pass failed to meet the HC cut point.

4.4 Calculating mass emissions

An assessment of emission reductions must be based on mass emission factors. However, Drive Clean does not at present operate a mass emission testing facility. Use of a constant volume sampler (CVS), which takes samples on a constant volume basis allowing one to calculate mass from concentration. This permits application of a common performance standard to all vehicles, regardless of engine size or weight.

Data from B.C. AirCare's mass emission testing facility was used to calculate mass emission factors for vehicles that passed inspection on the first attempt, vehicles that failed the first inspection and those vehicles in their final repaired state. The initial

inspection data for each vehicle in the CVS sample was categorized by vehicle type, model year and initial failure mode, and the AirCare readings were compared to the appropriate Drive Clean cut points to determine whether they would have passed an inspection in Ontario.

Finally, the quality of any subsequent repairs were placed into one of two categories: for the sake of simplicity, either "good" or "bad". The AirCare final inspection readings were expressed as ratio values (by dividing each by the Drive Clean cut points) and compared to the Drive Clean "good" ratio values. If the average of the three emission readings was close to the cut point, the repairs were classified as "bad".

After averaging, some interpolation, and adjustments to accommodate some unlikely combinations with very small sample sizes, the mass emission factors are as shown in Table 4. It should be noted that the mass emission factors are based on the results of the Hot505 testing regime which measures the emissions from driving under Phase 3 of the Federal Test Procedure.

4.5 Estimating emissions reductions

In calculating the emissions reductions by Ontario's Drive Clean program, each vehicle in the fleet is allocated both a pre- and a post-inspection and maintenance (I/M) emission factor. The emission reduction is simply the difference between the total pre-I/M and total post-I/M emissions.

For each model year and vehicle type, a count was conducted of the number of vehicles that passed, the number that failed in each of the possible failure modes (i.e., which of the emission cut points they were unable to meet), and the number that passed on re-inspection, were granted a conditional pass, or had not returned for a re-inspection. It was assumed that all failed vehicles will eventually receive either a pass certificate or a conditional pass certificate. Where repairs were made, the number of "good" versus "bad" repairs was computated.

In order to calculate the annual emissions reductions, counts were multiplied by factors derived from comparing the estimated fleet size with the actual numbers of vehicles tested. For example, the fleet size of even-year models between 1980 and 1996 was estimated as twice the number of vehicles inspected (in the first half-year of operation). For odd-year models, a factor of five was used (because only 20 % of vehicles from those years were inspected). Similarly, the numbers of pre-1980 and post-1996 vehicles were estimated.

To assess total pre-I/M emissions each vehicle which was not inspected in the first half-year had to be allocated as either passing or failing in one of the possible failure modes. This was done in proportion to the numbers from the same model year and vehicle type which were actually inspected.

It was also necessary to address those vehicles which had failed an inspection but have not yet returned to be re-inspected. At this early stage of the program, it is impossible to know how many of these vehicles may have been retired, so it has been assumed that they will all eventually achieve either a pass or a waiver. They have been categorized as either "good" or "bad" repairs, in accordance with the trend for their model years and vehicle types.

Initial (pre-I/M) annual emissions were calculated by multiplying the number of vehicles in the fleet by the initial condition grams/km and by the annual average distance for the model year. A similar calculation is performed for final (post-I/M) annual emissions. This calculation is more complex because it is the sum of vehicles which do not change, those that achieve a "good" repair, and those that achieve a "bad" repair.

Based on this analysis (Table 5), the calculated emissions reductions achieved during the data collection period (January 2, 1999 to September 30, 1999) was 5.9 % HC, 5.9 % CO, and 2.3 % NOx. Again, these calculations represent emissions reductions from half of the eligible fleet. Direct extrapolation for Year One (January 2, 1999 to December 31, 1999) results in estimated emissions reductions of 8.8 % HC, 8.8 % CO and 3.5 % NOx. Note that in Year One the program was in effect for nine

months (75 % fleet). Extrapolated to a complete program year (12 months, 100 % of eligible fleet), the estimated reductions are 11.8 % HC, 11.8 % CO, and 4.6 % NOx.

The impact of removing the repair cost limit, as anticipated for December 31, 2000 in the Phase I program area, was also assessed. Table 6 shows that if all repairs are "good", it is expected that *additional* emission reductions of 4.4 % HC, 2.9 % CO, and 1.1 % NOx are achievable during a complete program year in the Phase I program area.

4.6 Impact on fuel consumption

The B.C. AirCare program has developed a methodology for determining how fuel consumption can be affected by the repairs intended to correct an emissions problem (see *AirCare Program Review and Evaluation of Benefits, Years One to Five*, Insurance Corporation British Columbia, December 1998). Although it is normal to expect such repairs to improve fuel consumption, in some cases a "good" repair can actually result in increased fuel consumption.

AirCare's tentative conclusion was that the average fuel consumption improvement for all repaired vehicles could be estimated at 2.26 %. For the first year of Drive Clean, the number of failed (and assumed to be repaired) vehicles has been calculated as 214,550. The average annual travel distance for this group is 15,300 km. If average fuel consumption is estimated at 10 litres/100 km, the annual fuel savings would be 7.42 million litres. This equates to a reduction in carbon dioxide emissions of approximately 18,500 tonnes.

5.0 Conclusions

The analysis of the nine months of data collection (equivalent to about half the eligible fleet) under Ontario's Drive Clean indicates that the mandatory inspection and maintenance program has achieved significant reductions in the emissions of

contaminants that contribute to photochemical smog and other environmental problems.

Nearly 84 % of light-duty vehicles inspected received a pass certificate upon first inspection, with the pass rate rising to more than 95 % for vehicles less than five years old. The repairs not only resulted in *actual* reductions for each of the emission parameters, these reductions were substantially below the cut points.

The repairs undertaken on vehicles that failed their first inspection resulted in significant emission reductions. In Year One of Drive Clean, it is estimated that reductions of 8.8 % HC, 8.8 % CO, and 3.5 % NOx were achieved from 1999 base levels from vehicle sources in the Phase I program area. Annualized over a full year, the program will achieve an estimated reductions of 11.8 % HC, 11.7 % CO, and 4.7 % NOx. The phase-out of the repair cost limit after December 2000 in the Phase I program area can expect *additional annual* reductions in HC by 4.4 %, CO by 2.9 % and NOx by 1.1 %. In addition, concurrent improvements in fuel efficiency reduced the release of carbon dioxide, a greenhouse gas, by an estimated 18,500 tonnes.

TABLES

Rates of inspection, failure, reinspection, and conditional pass
by vehicle type and model year
for individual vehicles

vehicle type	model year	number of vehicles: inspected	failed	reinspected	passed reinspection	conditional passed	failed reinspection	% of inspected: failure rate	% of failed: reinspection rate	% of reinspected: reinspection pass rate	reinspection conditional pass rate	reinspection fail rate
VTYPE	MYEAR	VCOUNT	FCOUNT	RCOUNT	RPCOUNT	RWCOUNT	RFCOUNT	FRATE	RRATE	RPRATE	RWRATE	RFRATE
P	1980	1673	926	740	341	247	268	55	80	46	33	36
P	1981	574	315	215	163	18	95	55	68	76	8	44
P	1982	3750	2044	1681	765	552	644	55	82	46	33	38
P	1983	1093	561	357	268	19	160	51	64	75	5	45
P	1984	14734	8063	6769	3290	2037	2633	55	84	49	30	39
P	1985	4295	2068	1387	1046	107	667	48	67	75	8	48
P	1986	41443	17850	14744	7600	4214	5500	43	83	52	29	37
P	1987	10629	3842	2707	2078	174	1252	36	70	77	6	46
P	1988	73819	19207	15778	8890	4190	5429	26	82	56	27	34
P	1989	15466	3574	2529	2078	119	1010	23	71	82	5	40
P	1990	79689	12614	10434	6600	2355	3306	16	83	63	23	32
P	1991	13415	2118	1618	1386	67	602	16	76	86	4	37
P	1992	77525	10045	8257	5327	1763	2699	13	82	65	21	33
P	1993	11644	1190	933	792	43	341	10	78	85	5	37
P	1994	67818	2875	2420	1800	361	661	4	84	74	15	27
P	1995	14534	404	371	333	12	95	3	92	90	3	26
P	1996	60795	853	784	681	50	140	1	92	87	6	18
P	1997	16339	271	248	232		61	2	92	94		25
P	1998	13191	86	82	79	2	4	1	95	96	2	5
P	1999	5610	37	27	23	3	2	1	73	85	11	7
P	2000	51	1					2				
T	1980	321	157	131	68	30	51	49	83	52	23	39
T	1981	87	30	22	16	2	8	34	73	73	9	36
T	1982	469	217	192	105	43	77	46	88	55	22	40
T	1983	105	60	40	33	3	15	57	67	83	8	38
T	1984	1677	878	735	317	238	307	52	84	43	32	42
T	1985	607	330	213	157	17	107	54	65	74	8	50
T	1986	5315	2497	2090	979	658	817	47	84	47	31	39
T	1987	1546	687	489	395	34	231	44	71	81	7	47
T	1988	12328	4123	3536	2014	898	1232	33	86	57	25	35
T	1989	2750	819	630	521	33	260	30	77	83	5	41
T	1990	13243	2791	2403	1612	464	729	21	86	67	19	30
T	1991	2223	308	261	226	10	95	14	85	87	4	36
T	1992	13119	2492	2179	1316	551	733	19	87	60	25	34
T	1993	2583	370	289	239	8	111	14	78	83	3	38
T	1994	15241	597	547	409	79	154	4	92	75	14	28
T	1995	4132	129	108	97	4	30	3	84	90	4	28
T	1996	17968	215	206	172	17	59	1	96	83	8	29
T	1997	4994	36	47	44		10	1	131	94		21
T	1998	2583	26	18	17		1	1	69	94		6
T	1999	1649	8	7	7			0	88	100		
T	2000	11										

P = Passenger

T = Truck (< 4500 kg)

Table 1

Modal Failure rates

vehicle type VTYPE	model year MYEAR	number of initial inspections ICOUNT	number of failed initial inspections FCOUNT	number of initial inspections which include HC failure HCFCOU	number of initial inspections which include CO failure COFCOU	number of initial inspections which include NO failure NOFCOU	failure rate as % of initial inspections FRAT	HC fail rate as % of failed initial inspections HCFRAT	CO fail rate as % of failed initial inspections COFRAT	NO fail rate as % of failed initial inspections NOFRAT
P	1980	1863	1048	715	637	503	56.3	68.2	60.8	48.0
P	1981	706	397	303	248	163	56.2	76.3	62.5	41.1
P	1982	4063	2219	1547	1330	959	54.6	69.7	59.9	43.2
P	1983	1220	643	472	378	287	52.7	73.4	58.8	44.6
P	1984	16008	8829	5296	4201	5385	55.2	60.0	47.6	61.0
P	1985	4833	2351	1453	1278	1276	48.6	61.8	54.4	54.3
P	1986	44631	19529	12448	10289	10422	43.8	63.7	52.7	53.4
P	1987	11766	4429	3053	2570	1962	37.6	68.9	58.0	44.3
P	1988	78598	21325	19061	11021	11044	27.1	89.4	51.7	51.8
P	1989	16601	4101	3526	2258	2251	24.7	86.0	55.1	54.9
P	1990	83941	14053	10621	7100	9593	16.7	75.6	50.5	68.3
P	1991	14405	2460	2006	1361	1648	17.1	81.5	55.3	67.0
P	1992	82269	11320	6231	3741	9895	13.8	55.0	33.0	87.4
P	1993	12342	1410	1042	541	1049	11.4	73.9	38.4	74.4
P	1994	71553	3225	2021	1269	2310	4.5	62.7	39.3	71.6
P	1995	15621	450	350	218	277	2.9	77.8	48.4	61.6
P	1996	65288	991	585	514	575	1.5	59.0	51.9	58.0
P	1997	19693	296	144	217	121	1.5	48.6	73.3	40.9
P	1998	14915	90	34	22	36	0.6	37.8	24.4	40.0
P	1999	6371	39	7	2	38	0.6	17.9	5.1	97.4
P	2000	52	1	1		1	1.9	100.0	0.0	100.0
T	1980	331	164	96	93	61	49.5	58.5	56.7	37.2
T	1981	109	43	36	21	21	39.4	83.7	48.8	48.8
T	1982	489	230	131	104	109	47.0	57.0	45.2	47.4
T	1983	115	65	43	44	22	56.5	66.2	67.7	33.8
T	1984	1799	953	654	574	428	53.0	68.6	60.2	44.9
T	1985	695	380	258	255	169	54.7	67.9	67.1	44.5
T	1986	5725	2730	1921	1453	1280	47.7	70.4	53.2	46.9
T	1987	1711	781	655	346	378	45.6	83.9	44.3	48.4
T	1988	13107	4526	4280	2014	2019	34.5	94.6	44.5	44.6
T	1989	2991	943	919	444	398	31.5	97.5	47.1	42.2
T	1990	13862	3036	3036	1187	1450	21.9	100.0	39.1	47.8
T	1991	2347	351	351	143	153	15.0	100.0	40.7	43.6
T	1992	13819	2786	2786	1338	1582	20.2	100.0	48.0	56.8
T	1993	2778	466	466	226	247	16.8	100.0	48.5	53.0
T	1994	15743	722	717	354	324	4.6	99.3	49.0	44.9
T	1995	4279	141	133	87	72	3.3	94.3	61.7	51.1
T	1995	18556	235	143	134	149	1.3	60.9	57.0	63.4
T	1997	5280	37	18	15	18	0.7	48.6	40.5	48.6
T	1998	2638	26	5	3	15	1.0	19.2	11.5	57.7
T	1999	1678	8	3	3	1	0.5	37.5	37.5	12.5
T	2000	11	0	0	0	0	0.0	0.0	0.0	0.0

P = Passenger
T = Truck (< 4500 kg)

Table 2

Table 3

Measures of repair effectiveness

	Median Emission Ratio (emission reading/cutpoint)		
	HC	CO	NO
all initial inspections	0.39	0.20	0.24
first failure	1.30	0.94	1.09
final pass	0.51	0.18	0.40
final conditional pass	1.41	0.99	1.06

MEASURE 1

	Median reductions as proportion of initial readings		
	HC	CO	NO
final pass	0.51	0.75	0.53
final conditional pass	0.01	0.03	0.04

MEASURE 2

	Median 'closeness-to-zero' of final readings		
	HC	CO	NO
final pass	0.49	0.82	0 60
final conditional pass	-0.41	0.01	-0.06

Notes for Table 4

1. The table does not show every model year separately but, for reasons of size, groups model years into pre -1980, 1980,1987, 1988,1993, and 1994 and later; these age groups reflect the potential emissions performance of the vehicles, and are the age groups used to derive the mass emission factors from CVS data.

2. In the sixth column, the "number in fleet with initial condition" consists of vehicles which will actually be tested in this first year of the program, as well as those which are in the fleet but will not be inspected.

3. The "number not changing" comprises only those vehicles which were not inspected and will therefore not change in any way as a result of the program; all of the passed-first-time vehicles from column six are also taken as not changing.

4. The columns for "number achieving a final bad result" and "number achieving a final good result" include only those vehicles which have been, or will be, inspected in the first year of the program; these are the only vehicles which will deliver an emissions reduction benefit.

5. 1 Mg equals 1 tonne

6. These tonnages are Hot505 tonnages and represent the emissions which would be produced if all the vehicles always drove in a manner which reflected the third phase of the FTP (i.e., highway driving); it was assumed that the percentage reductions calculated from Hot505 emission factors can be applied to the overall inventory which was derived from the MOBILE model.

Table 4

Calculation of Emission Reductions by Vehicle Type and by Age Group

vehicle type	model years	HC result	CO result	NO result	number in fleet with initial condition	number not changing	number achieving bad final result	number achieving good final result	Mass Emission Factor: INITIAL RESULT g/km HC	CO	NO	FINAL OAO REPAIR g/km HC	CO	NO	FINAL GOOD REPAIR g/km HC	CO	NO	ANNUAL km	row total INITIAL H505 Mg HC	CO	NO	row total FINAL H505 Mg HC	CO	NO	row total REDUCTION H505Mg HC	CO	NO	row total % REDUCTION HC	CO	NO
P&T	pre 80				99000				1.25	15.63	1.94							7000	866	10828	1343	866	10828	1343						
P	1980-87	F	F	F	11388	4808	2922	3658	2.35	34.28	3.15	2.00	25.18	2.55	0.97	12.31	1.50	12000	321	4685	431	248	3401	337	72	1284	94	22.6	27.4	21.8
P	1980-87	F	F	P	40914	18266	9253	13395	2.35	34.28	1.07	2.00	25.18	1.07	0.97	12.31	1.50	12000	1152	16832	524	892	12280	593	259	4544	-69	22.5	27.0	-13.2
P	1980-87	F	P	F	13640	5622	3513	4505	2.35	11.98	3.15	2.00	11.98	2.55	0.97	12.31	1.50	12000	384	1960	516	295	1978	401	89	-18	115	23.1	-0.9	22.3
P	1980-87	F	P	P	11634	5160	2284	4190	2.35	11.98	1.07	2.00	11.98	1.07	0.97	12.31	1.50	12000	327	1672	149	249	1688	171	79	-17	-22	24.0	-1.0	-14.5
P	1980-87	P	F	F	3482	1338	775	1369	1.46	34.28	3.15	1.46	25.18	2.55	0.97	12.31	1.50	12000	61	1432	132	53	987	99	8	446	33	13.1	31.1	25.0
P	1980-87	P	F	P	12632	5822	1757	5053	1.46	34.28	1.07	1.46	25.18	1.07	0.97	12.31	1.50	12000	221	6187	192	192	3672	198	30	1525	-26	13.4	29.3	-16.1
P	1980-87	P	P	F	33290	12736	8910	11644	1.46	11.98	3.15	1.46	11.98	2.55	0.97	12.31	1.50	12000	583	4784	1260	515	4630	963	68	46	297	11.7	-1.0	23.6
P	1980-87	P	P	P	166222				0.57	9.19	1.27							12000	1127	18324	2540	1127	18324	2540						
P	1988-93	F	F	F	27038	10456	6044	10538	0.99	24.21	1.48	0.60	14.61	0.95	0.29	4.49	0.79	17000	454	11130	679	289	6611	501	165	4519	178	36.2	40.6	26.2
P	1988-93	F	F	P	38484	14810	6701	16973	0.99	24.21	0.64	0.60	14.61	0.64	0.29	4.49	0.79	17000	646	15642	418	401	9058	460	245	6784	-42	37.9	42.8	-10.2
P	1988-93	F	P	F	19966	7138	5332	7496	0.99	6.52	1.48	0.60	6.52	0.95	0.29	4.49	0.79	17000	335	2213	501	211	1955	366	124	258	136	37.0	11.7	27.0
P	1988-93	F	P	P	19990	6792	4844	8354	0.99	6.52	0.64	0.60	6.52	0.64	0.29	4.49	0.79	17000	338	2216	217	205	1928	238	131	288	21	39.0	13.0	-9.6
P	1988-93	P	F	F	3306	1176	731	1399	0.46	24.21	1.48	0.46	14.61	0.95	0.29	4.49	0.79	17000	26	1361	63	22	773	60	4	588	23	15.5	43.2	27.7
P	1988-93	P	F	P	5240	1880	778	2582	0.46	24.21	0.64	0.46	14.61	0.64	0.29	4.49	0.79	17000	41	2157	57	34	1164	63	7	993	-8	18.0	46.0	-11.4
P	1988-93	P	P	F	38918	12296	11356	15266	0.46	6.52	1.48	0.46	6.52	0.95	0.29	4.49	0.79	17000	305	4315	677	261	3789	897	44	526	281	14.3	12.2	28.7
P	1988-93	P	P	P	719676				0.17	2.64	0.38							17000	2033	32278	4593	2033	32278	4593						
P	1994-2000	F	F	F	1634	620	307	707	0.50	7.05	1.34	0.50	3.87	1.19	0.13	2.50	0.23	22000	18	254	48	12	161	30	6	92	18	31.8	36.4	37.9
P	1994-2000	F	F	P	2548	1172	210	1166	0.50	7.05	0.15	0.50	3.87	0.15	0.13	2.50	0.23	22000	28	395	9	18	264	11	6	132	2	33.4	33.3	23.2
P	1994-2000	F	P	F	1490	814	205	371	0.50	2.81	1.34	0.50	2.81	1.19	0.13	2.50	0.23	22000	16	92	44	13	80	34	3	3	10	18.2	2.8	22.1
P	1994-2000	F	P	P	1782	756	178	828	0.50	2.81	0.15	0.50	2.81	0.15	0.13	2.50	0.23	22000	19	109	6	13	103	7	7	6	-1	34.3	5.2	-23.8
P	1994-2000	P	F	F	378	162	53	163	0.32	7.05	1.34	0.32	3.87	1.19	0.13	2.50	0.23	22000	3	59	11	2	38	7	1	20	4	25.1	34.2	37.2
P	1994-2000	P	F	P	2034	978	153	903	0.32	7.05	0.15	0.32	3.87	0.15	0.13	2.50	0.23	22000	14	316	7	11	214	8	4	101	-2	25.9	32.1	-22.6
P	1994-2000	P	P	F	5262	2060	1345	1857	0.32	2.81	1.34	0.32	2.81	1.19	0.13	2.50	0.23	22000	37	326	155	30	313	105	8	13	50	20.6	3.9	32.0
P	1994-2000	P	P	P	825914				0.13	1.82	0.23							22000	2362	32982	4179	2362	32982	4179						
T	1980-87	F	F	F	1582	806	343	433	2.35	34.28	3.15	2.00	25.18	2.55	0.97	12.31	1.50	12000	45	651	60	36	499	49	9	152	11	19.2	23.3	18.6
T	1980-87	F	F	P	6006	2788	1352	1866	2.35	34.28	1.07	2.00	25.18	1.07	0.97	12.31	1.50	12000	189	2471	77	133	1831	87	38	640	-10	21.5	25.9	-12.5
T	1980-87	F	P	F	2780	1428	675	777	2.35	11.98	3.15	2.00	11.98	2.55	0.97	12.31	1.50	12000	78	400	105	63	403	86	15	-3	20	19.4	-0.8	18.7
T	1980-87	F	P	P	2616	1304	447	865	2.35	11.98	1.07	2.00	11.98	1.07	0.97	12.31	1.50	12000	74	376	33	58	378	38	16	-3	4	21.9	-0.6	-13.3
T	1980-87	P	F	F	614	302	137	175	1.46	34.28	3.15	1.46	25.18	2.55	0.97	12.31	1.50	12000	11	253	23	10	192	19	1	61	4	6.5	24.2	18.3
T	1980-87	P	F	P	1778	676	343	759	1.46	34.28	1.07	1.46	25.18	1.07	0.97	12.31	1.50	12000	31	731	23	27	494	27	4	238	4	14.2	32.5	-17.2
T	1980-87	P	P	F	3336	1352	848	1136	1.46	11.98	3.15	1.46	11.98	2.55	0.97	12.31	1.50	12000	58	476	126	52	484	67	7	-5	28	11.4	-0.9	22.8
T	1980-87	P	P	P	20466				0.57	9.19	1.27							12000	142	2300	319	142	2300	319						
T	1988-93	F	F	F	3882	1312	1045	1525	1.92	26.24	1.81	1.80	20.19	1.80	0.46	6.77	0.92	17000	127	1732	126	87	1171	99	40	560	28	31.5	32.4	22.0
T	1988-93	F	F	P	8824	3652	1814	4358	1.92	26.24	0.54	1.80	20.19	0.54	0.46	6.77	0.92	17000	321	4383	90	209	2902	119	112	1481	-28	34.9	33.8	-31.1
T	1988-93	F	P	F	4796	1316	1453	2027	1.92	10.24	1.81	1.80	10.24	1.80	0.46	6.77	0.92	17000	157	835	156	103	784	119	53	61	37	34.0	6.1	23.7
T	1988-93	F	P	P	8632	2842	1630	3960	1.92	10.24	0.54	1.80	10.24	0.54	0.46	6.77	0.92	17000	282	1503	80	180	1404	105	102	89	-20	36.2	6.6	32.1
T	1988-93	P	F	F	564	214	95	255	1.01	26.24	1.81	1.01	20.19	1.80	0.46	6.77	0.92	17000	10	252	18	7	166	14	2	88	4	24.4	34.0	24.5
T	1988-93	P	F	P	870	240	145	485	1.01	26.24	0.54	1.01	20.19	0.54	0.46	6.77	0.92	17000	15	388	8	10	229	11	4	159	-3	30.0	40.9	-39.0
T	1988-93	P	P	F	5290	1768	1416	2106	1.01	10.24	1.81	1.01	10.24	1.80	0.46	6.77	0.92	17000	90	821	172	71	868	134	19	53	38	21.4	5.7	22.3
T	1988-93	P	P	P	120326				0.46	6.08	0.92							17000	941	12410	1882	941	12410	1882						
T	1994-2000	F	F	F	586	276	71	239	0.50	7.05	1.40	0.50	3.87	1.19	0.18	3.41	0.50	22000	6	91	18	5	67	13	2	24	5	26.5	26.5	28.1
T	1994-2000	F	F	P	888	444	88	456	0.50	7.05	0.24	0.50	3.87	0.15	0.18	3.41	0.50	22000	11	153	5	8	111	8	3	43	-2	30.0	27.9	44.6
T	1994-2000	F	P	F	242	140	23	79	0.50	2.81	1.40	0.50	2.81	1.19	0.18	3.41	0.50	22000	3	15	7	2	16	6	1	-1	2	21.2	-7.0	22.5
T	1994-2000	F	P	P	556	146	119	291	0.50	2.81	0.24	0.50	2.81	0.15	0.18	3.41	0.50	22000	6	34	3	4	38	4	2	-4	-1	34.0	-11.2	-46.5
T	1994-2000	P	F	F	56	10	12	34	0.32	7.05	1.40	0.32	3.87	1.19	0.18	3.41	0.50	22000	0	9	2	0	5	1	0	4	1	27.4	41.1	42.5
T	1994-2000	P	F	P	134	62	12	60	0.32	7.05	0.24	0.32	3.87	0.15	0.18	3.41	0.50	22000	1	21	1	1	15	1	0	6	-0	20.1	27.2	-43.0
T	1994-2000	P	P	F	738	310	148	282	0.32	2.81	1.40	0.32	2.81	1.19	0.18	3.41	0.50	22000	5	48	23	4	49	16	1	4	6	17.0	-8.1	27.5
T	1994-2000	P	P	P	210778				0.18	3.41	0.50							22000	847	16477	2399	847	16477	2399						
																		TOTAL	15146	218710	24797	13357	193035	23644	1792	25675	1153	11.8	11.7	4.7

P = Passenger T = Truck

Table 5

Summary of annual emission reductions from existing program, and all good repairs

Light-Duty Vehicles Emissions Reductions	% HC	% CO	% NO
For Full Program Year	11.8	11.7	4.7
For Full Program Year if all repairs are completed	16.2	14.7	5.7

Table 6

Calculation of emission reductions by vehicle type (P/T) and by age group, if all repairs were completed

										Mass Emission Factor																		
										INITIAL RESULT g/km			FINAL GOOD REPAIR g/km				row total INITIAL H505 Mg			row total FINAL H505 Mg if all completed repairs			row total REDUCTION H505Mg if all completed repairs			row total % REDUCTION if all completed repairs		
vehicle type	model years	HC result	CO result	NO result	number in fleet with initial condition	number not changing	number achieving bad final result	number achieving good final result	number achieving good final result	HC	CO	NO	HC	CO	NO	ANNUAL km	HC	CO	NO	HC	CO	NO	HC	CO	NO	HC	CO	NO
P&T	pre 80		x		69000					1.25	15.63	1.94				7000	800	10828	1343	866	10828	1343						
P	1980 87	F	F	F	11388	4808	2922	3058	6580	2.35	34.28	3.15	0.97	12.31	1.50	12000	321	4685	431	212	2850	300	108	1735	131	33.8	37.0	30.4
P	1980 87	F	F	P	40914	18266	9253	13395	22648	2.35	34.28	1.07	0.97	12.31	1.50	12000	1152	16832	524	778	10859	640	373	5973	-117	32.4	35.5	-22.2
P	1980 87	F	P	F	13640	5622	3513	4505	8018	2.35	11.98	3.15	0.97	12.31	1.50	12000	384	1960	516	252	1992	357	132	-32	160	34.4	-1.6	30.8
P	1980-87	F	P	P	11634	5160	2284	4190	6474	2.35	11.98	1.07	0.97	12.31	1.50	12000	327	1672	149	221	1698	182	107	-26	-33	32.6	-1.5	-22.4
P	1980 87	P	F	F	3482	1338	775	1369	2144	1.48	34.28	3.15	0.97	12.31	1.50	12000	61	1432	132	48	867	89	13	565	43	20.6	39.5	32.4
P	1980 87	P	F	P	12032	5822	1757	5053	6810	1.48	34.28	1.07	0.97	12.31	1.50	12000	221	5197	162	181	3401	197	40	1796	-35	18.0	34.6	-21.7
P	1980 87	P	P	F	33290	12736	8910	11644	20554	1.48	11.98	3.15	0.97	12.31	1.50	12000	583	4784	1280	483	4865	851	120	-81	408	20.6	-1.7	32.5
P	1980 87	P	P	P	166222					0.57	9.19	1.27				12000	1127	18324	2540	1127	18324	2540						
P	1988 93	F	F	F	27038	10456	6044	10538	16582	0.89	24.21	1.48	0.29	4.49	0.79	17000	454	11130	679	256	5571	484	198	5559	195	43.2	48.9	28.7
P	1988 93	F	F	P	38484	14810	6701	16973	23874	0.89	24.21	0.64	0.29	4.49	0.79	17000	646	15842	418	366	7905	477	280	7938	-59	43.3	50.1	-14.2
P	1988 93	F	P	F	19966	7138	5332	7496	12828	0.89	6.52	1.48	0.29	4.49	0.79	17000	335	2213	501	184	1771	351	152	442	151	45.2	20.0	30.1
P	1988 93	F	P	P	19990	8792	4844	8354	13198	0.88	6.52	0.64	0.29	4.49	0.79	17000	336	2216	217	180	1761	250	156	455	33	46.5	20.5	-15.2
P	1988 93	P	F	F	3300	1170	731	1399	2130	0.46	24.21	1.48	0.29	4.49	0.79	17000	20	1361	83	20	647	58	6	714	25	23.6	52.5	30.2
P	1988-93	P	F	P	5240	1880	778	2582	3360	0.46	24.21	0.64	0.29	4.49	0.79	17000	41	2157	57	31	1031	65	10	1120	8	23.5	52.2	-14.8
P	1988 93	P	P	F	38918	12200	11356	15266	26622	0.46	6.52	1.48	0.29	4.49	0.79	17000	305	4315	977	229	3397	664	76	917	313	25.0	21.3	32.0
P	1988 93	P	P	P	719676					0.17	2.64	0.38				17000	2033	32278	4593	2033	32278	4503						
P	1994 2000	F	F	F	1634	620	307	707	1014	0.50	7.05	1.34	0.13	2.50	0.23	22000	18	254	48	10	152	23	8	102	25	45.3	40.1	51.4
P	1994 2000	F	F	P	2548	1172	210	1166	1376	0.50	7.05	0.15	0.13	2.50	0.23	22000	28	395	9	17	258	11	11	138	-2	39.4	34.8	-27.4
P	1994 2000	F	P	F	1490	914	205	371	576	0.50	2.81	1.34	0.13	2.50	0.23	22000	10	92	44	12	68	30	5	4	14	28.2	4.3	32.0
P	1994 2000	F	P	P	1782	756	178	828	1006	0.50	2.81	0.15	0.13	2.50	0.23	22000	19	109	6	11	102	8	6	7	-2	41.7	6.4	-29.0
P	1994 2000	P	F	F	378	162	53	163	216	0.32	7.05	1.34	0.13	2.50	0.23	22000	3	59	11	2	37	6	1	22	5	33.3	38.8	47.3
P	1994 2000	P	F	P	2034	978	153	903	1056	0.32	7.05	0.15	0.13	2.50	0.23	22000	14	316	7	10	210	9	4	106	-2	30.3	33.5	-26.4
P	1994 2000	P	P	F	5262	2060	1345	1857	3202	0.32	2.81	1.34	0.13	2.50	0.23	22000	37	326	155	24	304	77	13	22	78	35.5	6.8	50.4
P	1994 2000	P	P	P	825914					0.13	1.82	0.23				22000	2362	32082	4179	2362	32082	4179						
T	1980 87	F	F	F	1582	806	343	433	776	2.35	34.28	3.15	0.97	12.31	1.50	12000	45	651	66	32	446	44	13	205	15	28.7	31.4	25.8
T	1980 87	F	F	P	6000	2788	1352	1866	3218	2.35	34.28	1.07	0.97	12.31	1.50	12000	109	2471	77	116	1622	93	53	849	17	31.4	34.3	-21.5
T	1980 87	F	P	F	2786	1428	575	777	1352	2.35	11.98	3.15	0.97	12.31	1.50	12000	78	400	105	56	405	78	22	-5	27	28.5	1.3	25.8
T	1980 87	F	P	P	2616	1304	447	865	1312	2.35	11.98	1.07	0.97	12.31	1.50	12000	74	370	33	52	381	40	22	-5	-7	28.4	1.4	-20.2
T	1980 87	P	F	F	614	302	137	175	312	1.48	34.28	3.15	0.97	12.31	1.50	12000	11	253	23	9	170	17	2	82	0	17.0	32.6	26.7
T	1980 87	P	F	P	1776	676	343	759	1102	1.48	34.28	1.07	0.97	12.31	1.50	12000	31	731	23	25	441	26	6	291	-6	20.7	39.7	-24.9
T	1980 87	P	P	F	3330	1352	848	1136	1984	1.48	11.98	3.15	0.97	12.31	1.50	12000	56	479	126	47	467	87	12	8	39	19.9	1.6	31.3
T	1980 87	P	P	P	20866					0.57	9.19	1.27				12000	142	2300	319	142	2300	319						
T	1988 93	F	F	F	3882	1312	1045	1525	2570	1.92	26.24	1.91	0.46	8.77	0.92	17000	127	1732	126	83	968	83	64	763	43	50.2	44.1	34.3
T	1988 93	F	F	P	9824	3652	1814	4358	6172	1.92	26.24	0.54	0.46	8.77	0.92	17000	321	4383	90	166	2549	130	153	1833	40	47.7	41.6	44.0
T	1988-93	F	P	F	4786	1310	1453	2027	3480	1.92	10.24	1.91	0.46	8.77	0.92	17000	157	835	156	71	746	97	86	87	59	55.1	10.4	37.6
T	1988 93	F	P	P	8832	2842	1830	3960	5790	1.92	10.24	0.54	0.46	8.77	0.92	17000	282	1503	80	139	1358	117	144	145	-37	50.9	9.6	47.0
T	1988 93	P	F	F	564	214	95	255	350	1.01	26.24	1.91	0.46	8.77	0.92	17000	10	252	18	6	148	12	3	104	6	33.4	41.3	32.2
T	1988-93	P	F	P	870	240	145	485	630	1.01	26.24	0.54	0.46	8.77	0.92	17000	15	388	8	9	201	12	6	187	4	38.0	48.2	-50.7
T	1988 93	P	P	F	5290	1768	1416	2106	3522	1.01	10.24	1.91	0.46	8.77	0.92	17000	86	921	172	58	833	113	32	88	50	35.8	9.6	34.5
T	1988 93	P	P	P	126326					0.46	6.08	0.92				17000	941	12430	1882	941	12430	1882						
T	1994-2000	F	F	F	588	270	71	239	310	0.50	7.05	1.40	0.18	3.41	0.50	22000	6	81	18	4	66	12	2	25	6	34.4	27.3	34.2
T	1994 2000	F	F	P	988	444	88	456	544	0.50	7.05	0.24	0.18	3.41	0.50	22000	11	153	5	7	110	8	4	44	3	35.8	28.4	-57.2
T	1994 2000	F	P	F	242	140	23	79	102	0.50	2.81	1.40	0.18	3.41	0.50	22000	3	15	7	2	16	5	1	-1	2	27.4	0.0	27.2
T	1994 2000	F	P	P	550	140	110	201	410	0.50	2.81	0.24	0.18	3.41	0.50	22000	6	34	3	3	40	5	3	-5	2	47.9	15.7	-76.7
T	1994 2000	P	F	F	50	10	12	34	46	0.32	7.05	1.40	0.18	3.41	0.50	22000	0	9	2	0	5	1	0	4	1	37.2	42.4	53.0
T	1994-2000	P	F	P	134	62	12	60	72	0.32	7.05	0.24	0.18	3.41	0.50	22000	1	21	1	1	15	1	0	6	-0	24.3	27.8	55.0
T	1994 2000	P	P	F	738	310	146	282	428	0.32	2.81	1.40	0.18	3.41	0.50	22000	5	48	23	4	51	14	1	-6	9	28.2	12.3	37.4
T	1994-2000	P	P	P	219776					0.18	3.41	0.50				22000	847	16477	2399	847	16477	2399						
																TOTAL	15148	218710	24797	12700	186548	23383	2449	32102	1414	16.2	14.7	5.7

P = Passenger T = Truck